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Real-Time Implementation of a 1.25-Gbit/s DMT Transmitter for Robust and Low-Cost LED-Based Plastic Optical Fiber Applications

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Abstract *Real-time implementation of a DMT transmitter in FPGA is demonstrated for low-cost, standard 1-mm step-index plastic optical fiber applications based on commercial resonant-cavity LED and large-diameter (540 µm) photodiode.*

Introduction

During the last years, the standard step-index polymer optical fibre (SI-POF) with 1-mm core diameter has established itself as the preferred transmission medium for short-range optical data communications in automotive multimedia networks (MOST25/150) with data rates up to 150 Mbit/s. These systems are all based on LED, because of the robustness and stability in terms of temperature behaviour and lifetime in comparison to laser diodes. Due to the rapid integration of numerous multimedia applications in automobiles such as (HD-) DVD-players, gaming, cameras for monitoring, etc., next generation systems should provide data rates in the Gigabit range while still keeping the LED as optical source. By use of discrete multitone[1] (DMT) or multilevel[2] modulation, it has been shown that the severe bandwidth limitations of LED, SI-POF, and large-area photodiode can be successfully overcome for enabling Gigabit transmission. However, until now, only offline signal processing has been used for proving the concept of Gigabit transmission over SI-POF with LEDs.

In this paper, first results regarding an FPGA-based implementation of a real-time DMT transmitter for 1.25-Gbit/s transmission over SI-POF are presented. A commercial resonant-cavity LED[3] (RC-LED) and a standard PIN photodiode with a large active-area diameter of 540 µm are used for optical transmission and reception respectively.

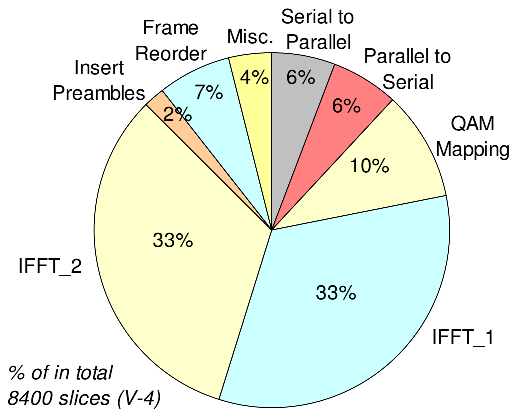

Fig. 2: Virtex-4 FPGA slices utilized in DMT transmitter according to functionality (normalized).

System Implementation

Fig. 1 shows a functional block diagram of the implementation of the DMT transmitter in FPGA (Xilinx Virtex-4 FX100). A PRBS sequence is generated as input source to the DMT modulator. This serial input sequence is serial-to-parallel converted and mapped onto different quadrature amplitude modulation (QAM) constellation points, implemented using read-only memory (ROM) cells. After this, the parallel QAM symbols are serialized because the pipelined IFFT-core expects serial input data. A demultiplexer (DEMUX) is needed to split the serial data into two parallel processing streams clocked at 312.5 MHz each because the FPGA cannot support a high clock frequency of 625 MHz.

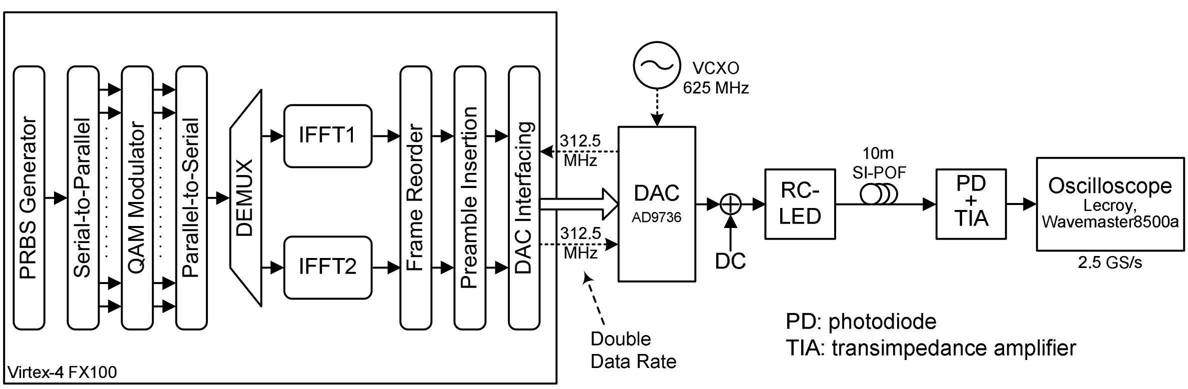

Fig. 1: FPGA implementation of DMT transmitter and experimental setup for performance evaluation.

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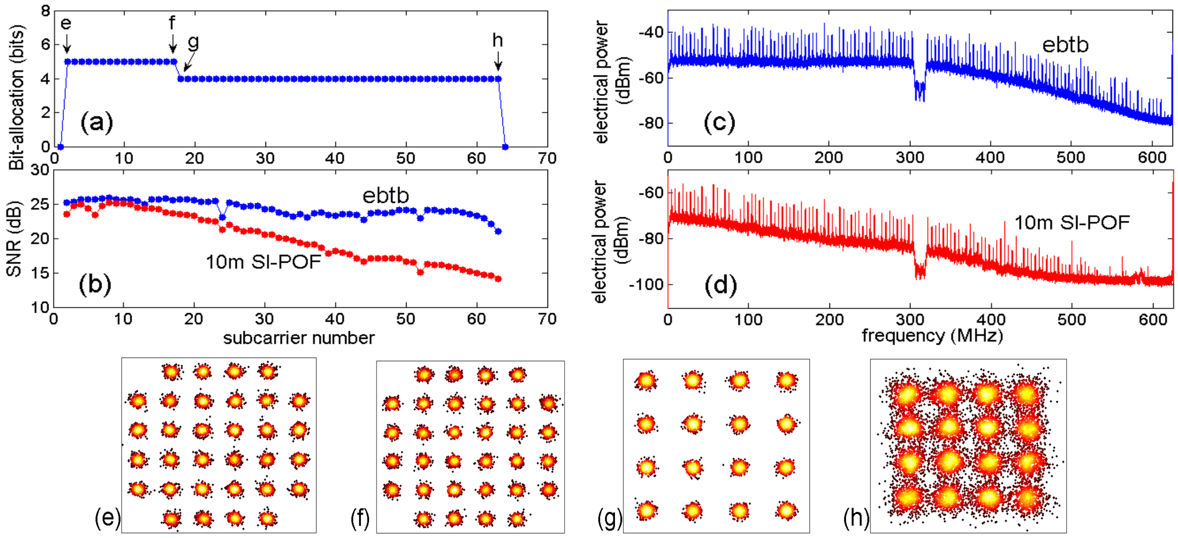

Fig. 3: (a) Bit-allocation per subcarrier. (b) Measured SNR per subcarrier for electrical back-to-back and after transmission over 10 m SI_POF. (c) Spectrum of DMT signal measured at electrical back-to-back and (d) after 10 m SI-POF. (e)-(h) Received constellation diagrams after 10 m SI-POF for subcarriers indicated by arrows shown in (a).

As a result, two IFFT-cores (clocked at 312.5 MHz each) are needed to process the data which is sent to the digital-to-analogue converter (DAC) at double data rate after reordering of the DMT frames and insertion of training preambles. The DAC works at a sampling speed of 625 MSamples/s.

Fig. 2 depicts the relative amount of resources needed for each of the functional blocks when everything is implemented using only FPGA slices. A Virtex-4 slice consists of two flip-flops and two 4-input look-up-tables. In the actual implementation, FPGA-specific hardware such as embedded multipliers and block RAMs are used so that full performance can be achieved. As expected, it can be seen from Fig. 2 that the IFFT core demands most resources. Depending on the speed of the DAC and therefore the bandwidth of the DMT signal, parallelization is needed because of limited chip/clocking rate. Higher DAC sampling speeds will require, relatively, more resources for IFFT processing due to the need for parallelization.

Experimental Results

The experimental setup for evaluating the performance of the DMT modulator is shown in Fig. 1. The DMT sequence generated by the DAC is used to drive an RC-LED for transmission over 10 m of SI-POF. Such distances are typical for automotive networks and the main limitation originates from the low bandwidth of the LED-based transmitter. The received optical power after 10 m SI-POF is -3 dBm and the modulation index is approximately 0.6. A large-diameter (540 µm) photodiode with integrated transimpedance amplifier is used to receive the optical signal and a digital storage oscilloscope sampling at 2.5 GSamples/s is used for demodulation and evaluation of the received DMT sequence. Fig. 3 shows the results of the real-time DMT transmitter. A 128-point IFFT is used for the DMT modulator where the first and last subcarriers are set to 0. Therefore, a total of 62 subcarriers are available and used for information transmission. The bit-allocation is depicted in Fig. 3a. A 4-point cyclic prefix is used and 10 preambles per 100 DMT frames are transmitted for training and channel estimation purposes. The bandwidth of the DMT signal is approximately 303 MHz, resulting in a bit-rate of 1.25 Gbit/s (1.125 Gbit/s after deduction of preamble overhead).

The signal-to-noise ratio (SNR) per subcarrier of the DMT transmitter is measured and plotted in Fig. 3b for both electrical back-to-back and transmission over 10 m SI-POF. The bandwidth limitation of the SI-POF channel can clearly be seen. The spectrum of the DMT signal is measured and depicted in Fig. 3c, where the signal power beyond 312.5 MHz is due to aliasing. This aliasing product is more suppressed in Fig. 3d as a result of the low bandwidth of the SI-POF channel. The received constellation diagrams (after 10 m SI-POF) of the subcarriers as depicted by the arrows in Fig. 3a are plotted in Fig. 3e-h.

Conclusions

For the first time, a real-time implementation of a 1.25-Gbit/s DMT transmitter has been reported. The performance was evaluated and transmission over 10 m of SI-POF using an RC-LED was successfully demonstrated. This proves that DMT is a promising candidate for upgrading conventional LED-based SI-POF automotive networks to enable Gigabit transmission using standard transceiver and SI-POF.

References

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